Industry Foundation Classes - Release 2.0

IFC Object Model Architecture Guide

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International Alliance for Interoperability

Enabling Interoperability in the AEC/FM Industry

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1 Introduction and Background

1.1 About this document

The document has been developed to serve as the underlying guide for the design of the IFC object model. The intended audience is the Specification Task Force (STF), the Technical Coordinators (TC's) of the constituent IAI chapters, and the technical co-chairs of the domain projects. The STF is responsible for applying these guidelines during the development of IFC object model specifications.

1.2 Assumptions and Abbreviations

This document assumes the reader is reasonably familiar with the following:

- AEC/FM market and project terminology
- Software industry terminology
- Concepts and terminology associated with object oriented software
- Concepts and terminology associated with information modeling

The following abbreviations are used throughout the IFC Specifications:

AEC/FM	Architectural, Engineering, Construction and Facilities Management
AP	Application Protocol
Arch	Architecture
CM	Construction Management
CORBA	Common Object Request Broker Architecture
COM	Microsoft's Component Object Model
DCE	Distributed Computing Environment
DCOM	Microsoft's Distributed Component Object Model
DSOM	IBM's Distributed System Object Model
FM	Facilities Management
FTP	File Transfer Protocol
GUID	Globally Unique Identifier
HVAC	Heating, Ventilating and Air Conditioning
HTTP	Hypertext Transport Protocol
IAI	International Alliance for Interoperability
IDL	Interface Definition Language
IFC	Industry Foundation Classes
IM	Information Model
ISO	International Standards Organization
FM	Facilities Management
MIDL	Microsoft's Interface Definition Language
ODL	Microsoft's Object Description Language
OMG	Object Management Group
ORB	Object Request Broker
OSF	Open Software Foundation
RPC	Remote Procedure Call
SOM	IBM's System Object Model
STEP	Standard for the Exchange of Product Model Data
TCP/IP	Transmission Control Protocol/Internet Protocol
TQM	Total Quality Management
URL	Universal Resource Locator

2 Baseline of IFC Model Architecture

The scope defined by the IAI for the IFC Object Model is "enabling interoperability between AEC/FM applications from different software vendors". The AEC/FM industry is, by its nature, fragmented and distributed. It also encompasses a very large set of object model requirements. Many axes can be described along which model requirements occur and can alter, such as:

- disciplines involved in AEC/FM processes
- life-cycle stages of AEC/FM projects
- level of detail required

In order to satisfy all model requirements the IFC Object Model has to be structured in order to allow both, diversification to cope with the various information axes, and centralization to harmonize and integrate the various diversified modules.

Development of an information model being of the size of the IFC Object Model requires team work and distributed responsibilities. The structure of the information model has to provide for both, encapsulated modules for relatively autonomous work, and overall rigid structure to facilitate a centralized integration of that work.

In understanding this, it becomes obvious that the IFC Object Model must be decomposed into smaller and more manageable modules, which are interconnected by a rigid overall structure. This document provides the rationale for such structure and presents the architecture for the IFC Object Model.

2.1 Short History of Information Modeling

The IFC Object Model, including its architecture, had been developed based on experience from earlier projects, most notably the European ESPRIT projects, ATLAS (7280), COMBI (6909), and VEGA (20408), and the development within ISO 10303, Product Data Representation and Exchange (STEP), most notably the Building Construction Core Model (BCCM)[1].

Information Modeling is nowadays a widely accepted methodology for the development of exchange protocol specification in engineering domains, such as architecture and building. The modeling approach or architecture had been further developed along the various projects carried out in various engineering domains. These developed from integration of applications in specialized domains to the development of a platform for interoperability through distributed product models. Another reason for different model approaches certainly was the state of knowledge at the corresponding time[2].

At the beginning two very generic models had been developed and the ideas (more than the actual content) are still influential. The General AEC Reference Model (GARM) was developed for the STEP project[3]. The GARM provides a first basic concept by introducing the 'Product Definition Unit' (PDU) and its subtypes 'functional unit' and 'technical solution'. The Building Systems Model (BSM), also shows a top down strategy to model a building[4]. It introduces functional systems as, e.g., enclosure, structural, mechanical, etc. and their entities.

The ESPRIT project IMPACT very intensively studied fundamental modeling principles as specialization, discrimination and orthogonalization as well as implementation principles as extension and instantiation. The model introduced the technique of ‘layered models', a concept to structure a number of models at different levels of abstraction. This architecture allows for the specification of Information Models with a larger scope.

The question remained how an information model that would cover the needs of all disciplines involved in the whole life cycle has to be structured. Several strategies had been developed to divide the universe of discourse into partial models. The ESPRIT project ATLAS defined 'view type models' and the ESPRIT

1 Wix, J. and Liebich, T. [1997] ISO TC 184/SC4/ WG3/N599, working draft, version T300

2 The following summary is an excerpt from Junge, R. and Liebich, T. [1998] Product Modeling Technology – the Foundation of Industry Foundation Classes, Amor, R. (ed.) *Product and Process Modeling in the Building Industry*, ISBN 1 86081 249 X

3 Gielingh, W., [1988] General AEC Reference Model, ISO TC 184/SC4/WG1 DOC N.3.2.2.1

4 Turner, J., [1990] Building Systems Model. ISO TC 184/SC4/WG1 Working paper

project COMBI uses 'partial models' and 'application models'. Although the solutions are slightly different, a way has been found that leads to practical information models for the building industry.

Next questions are raised, as how can partial models communicate. There are essential two strategies and a compromise.

1. There is a 'central' part of the modeling domain that would be shared by all partial models. Or, every entity that is shared by two or more 'views', as specified in partial models, has to reside in the central core. This approach assumes a homogeneous world. The philosophy is applied in STEP where every AP can only use and further constrain definitions already provided in the Integrated Generic Resources.
2. All partial models are autonomous and an intelligent kernel provides communication mechanism based on mapping techniques. This approach assumes a heterogeneous world. The ESPRIT project COMBI developed such an intelligent communicator.
3. The compromise approach defines a minimal kernel, that pre-harmonizes all partial models, but also provides for mapping mechanism to communicate with disperse models surrounding the harmonized part. The IFC Object Model follows this approach.

2.2 IFC Model Architecture Principles

The IFC Object Model Architecture has been developed using a set of principles governing it's organization and structure. These principles focus on basic requirements and can be summarized as:

- provide a modular structure to the model.
- provide a framework for sharing information between different disciplines within the AEC/FM industry.
- ease the continued maintenance and development of the model.
- enable information modelers to reuse model components
- enable software authors to reuse software components
- facilitate the provision of better upward compatibility between model releases

The IFC Object Model architecture provides a modular structure for the development of model components, the 'model schemas'. There are four conceptual layers within the architecture, which use a strict referencing hierarchy. Within each conceptual layer a set of model schemas is defined.

The first conceptual layer (shown at the bottom in Figure 1) provides Resource classes used by classes in the higher levels. The second conceptual layer provides a Core project model. This Core contains the Kernel and several Core Extensions. The third conceptual layer provides a set of modules defining concepts or objects common across multiple application types or AEC industry domains. This is the Interoperability layer. Finally, the fourth and highest layer in the IFC Object Model is the Domain/Applications Layer. It provides set of modules tailored for specific AEC industry domain or application type. Additionally, this layer contains specialized model 'adapters' to non-IFC domain/application models.

The architecture operates on a 'ladder principle'. At any layer, a class may reference a class at the same or lower layer but may not reference a class from a higher layer. References within the same layer must be designed very carefully in order to maintain modularity in the model design.

Inter-domain references at the Domain Models layer must be resolved through 'common concepts' defined in the Interoperability layer. If possible, references between modules at the Resource layer should be avoided in order to support the goal that each resource module is self-contained. However, there are some low level, general purpose resources, such as measurement and identification that are referenced by many other resources.

Ladder principle expanded:

1. Resource classes may only reference or use other Resources.
2. Core classes may reference other Core classes (subject to the limitations listed in 3) and may reference classes within the Resource layer without limitations. Core classes may not reference or use classes within the Interoperability or Domain/Applications layer.
3. Within the Core layer the 'ladder principle' also applies. Therefore, Kernel classes can be referenced or used by classes in the Core Extensions but the reverse is not allowed. Kernel classes my not reference Core Extension classes.

4. Interoperability layer classes can reference classes in the Core or Resource layers, but not in the Domain/Applications layer.
5. Domain/Applications layer classes may reference any class in the Interoperability, Core and Resource layers. Additionally, classes defined within custom Interoperability Adapters (interfaces to domain or application models developed by others) may reference classes within the Interoperability layer.

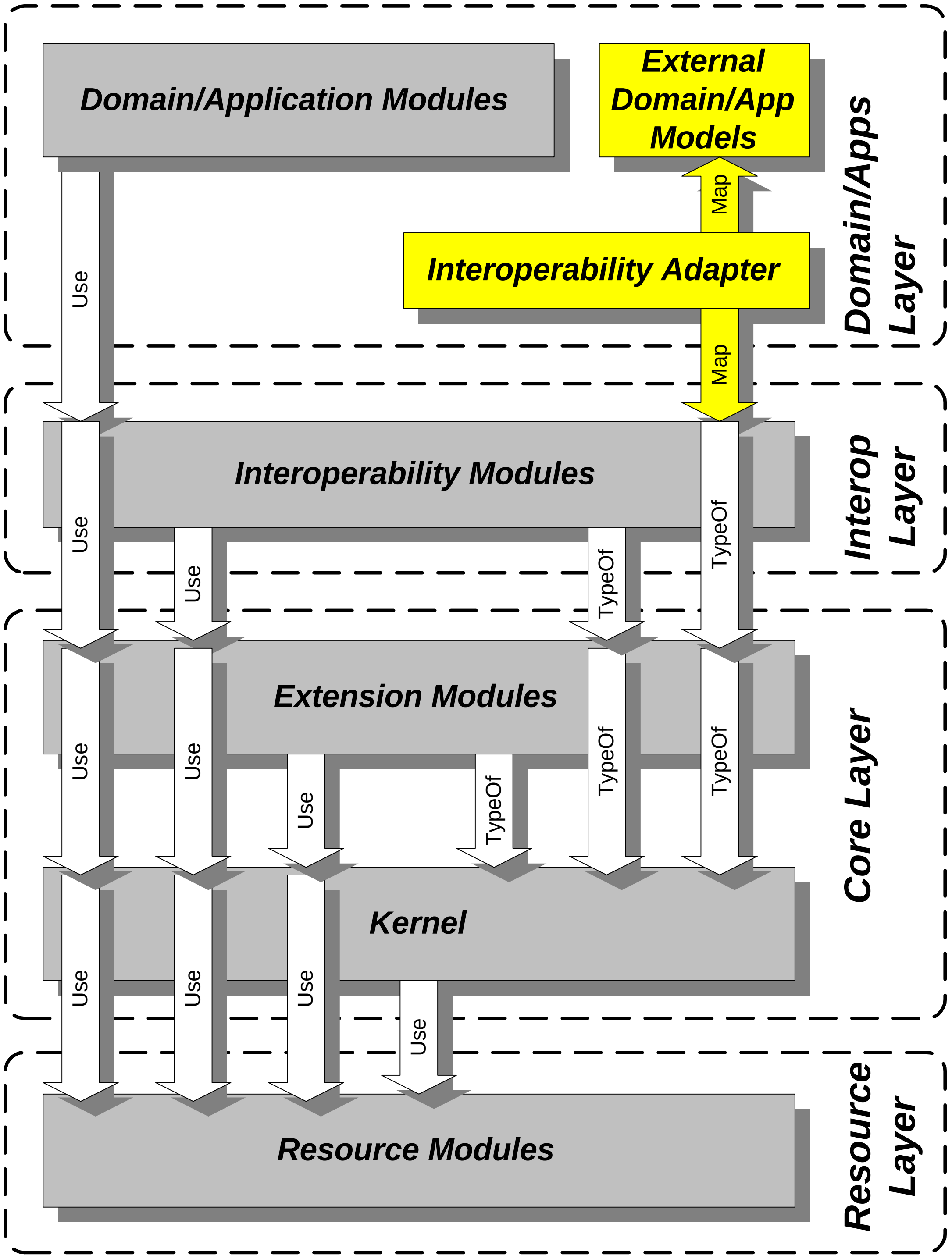


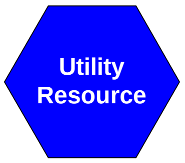
Figure 1 Layering Concept of IFC architecture

3 IFC Model Architecture Decomposition

The current version of the IFC Model Architecture for Release consists of the following layers, each of which will be discussed in turn.

- Resource Layer
- Core Layer
  - Kernel
  - Extensions
- Interoperability Layer
- Domain/Applications Layer

3.1 Resource Layer



Resources form the lowest layer in IFC Model Architecture and can be used or referenced by classes in the other layers. Resources can be characterized as general purpose or low level concepts or objects which do not rely on any other classes in the model for their existence. There are a few exceptions to this characterization. Classes from the Utility and Measure Resources are used by other, higher level resource classes.

All Resources represent individual business concepts. For instance, all information concerning the concept of cost is collected together within the cost schema, the IfcCostResource. Any classes within the Core, Interoperability or Domain/Application layers which need to use cost will reference this resource.

Similarly, all ideas concerning geometry are collected together within the IfcGeometryResource. Fundamental geometric entity definitions are defined in this resource. More specialized attribute driven geometry constructs are also defined here. Geometry will be referenced by classes defined within the Core and higher levels through the representation resource, also provided at the resource layer. However some details within the IfcGeometryResource are hidden from classes in these higher layers. There is no implication of choice for one of these representations coming from the resource layer, it simply provides the definition. A Core model object may utilize several geometry entities for representation.

3.1.1 Resource schemas for R1.5

Within the IFC Release 1.5 project scope the following resources schemas are included. Note that IFC Release 1.0 included many of these resources.

- IfcUtilityResource (object identification, object history, general purpose tables)
- IfcMeasureResource (units of measure, standard measurement types, custom measurement types)
- IfcGeometryResource (attribute driven geometric representation items, explicit geometric representation items, topological representation items, geometric models)
- IfcPropertyTypeResource (fundamental property types, property type definitions, property sets, shape representation)
- IfcPropertyResource (extended property types: material, cost, actor, classification, time)

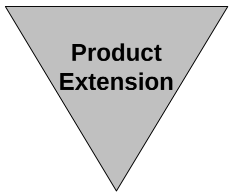
3.1.2 Resource schemas for R2.0

Within the IFC Release 2.0 project scope the following resource schemas are included. Note that IFC Release 2.0 further elaborates the modularity and encapsulation of resource schemas

- IfcUtilityResource
- IfcMeasureResource
- IfcGeometryResource
- IfcTopologyResource (was part of IfcGeometryResource in IFC Release 1.5)
- IfcGeometricModelResource (was part of IfcGeometryResource in IFC Release 1.5)
- IfcPropertyResource
- IfcMaterialResource (was part of IfcPropertyResource in IFC Release 1.5)
- IfcCostResource (was part of IfcPropertyResource in IFC Release 1.5)

- IfcActorResource (was part of IfcPropertyResource in IFC Release 1.5)
- IfcClassificationResource (was part of IfcPropertyResource in IFC Release 1.5)
- IfcDateAndTimeResource (was part of IfcPropertyResource in IFC Release 1.5)
- IfcRepresentationResource (was part of IfcPropertyResource in IFC Release 1.5)

3.2 Core Layer



The Core forms the next layer in IFC Model Architecture. Classes defined here can be referenced and specialized by all classes in the Interoperability and Domain/ Application layers. The Core layer provides the basic structure of the IFC object model and defines most abstract concepts that will be specialized by higher layers of the IFC object model.

The Core includes two levels of abstraction:

1. The Kernel
2. Core Extensions

Goals for Core Model Design:

- definition of the common superset of those concepts that later can be refined and used by various interoperability and domain models
- pre-harmonization of domain models by providing this common superset
- stable definition of the object model foundation to support upgrade compatible IFC Releases

3.2.1 Kernel

The Kernel provides all the basic concepts required for IFC models within the scope of the current IFC Release. The Kernel also determines the model structure and decomposition. Concepts defined in the kernel are, necessarily, abstracted to a high level. The kernel also includes fundamental concepts concerning the provision of objects, relationships, type definitions, attributes and roles. The Kernel can be envisioned as a kind of Meta Model that provides the platform for all model extensions. The constructs that form the Kernel are very generic and are *not* AEC/FM specific, although they will only be used for AEC/FM purposes due to the specialization by Core Extensions. The Kernel constructs will be included as a mandatory part of all IFC implementations.

The Kernel is the foundation of the Core Model. Kernel classes may reference classes in the Resource layer but may not reference those in the other parts of the Core or in higher level model layers. The use of Resources will be facilitated by well defined interfaces within resource schemata. Thus, the design detail for any particular resource will be hidden from referencing classes within the Kernel.

3.2.2 Core Extensions

Core Extensions, as the name implies, provide extension or specialization of concepts defined in the Kernel. Core Extensions are therefore, the first refinement layer for abstract Kernel constructs. More specifically, they extend Kernel constructs for use within the AEC/FM industry. Each Core Extension is a specialization of classes defined in the Kernel. Figure 2 shows the further specialization of classes rooted in the IfcKernel.

Beyond this class specialization, primary relationships and roles are also defined within the Core Extensions.

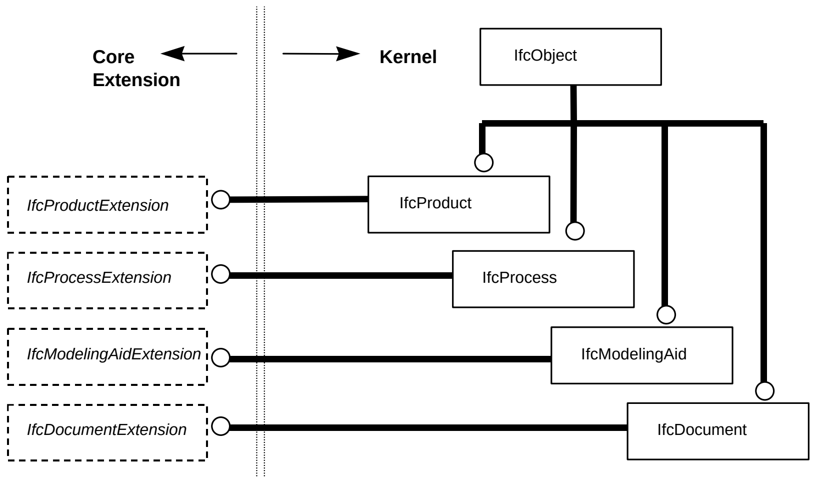


Figure 2 Core Extensions from Kernel Classes

A class defined within a Core Extension may be used or referenced by classes defined in the Inteoperability or Domain/Applications layers, but not by a class within the Kernel or in the Resource layer. References between Core Extensions have to be defined very carefully in a way that allows the selection of a singular Core Extension without destroying data integrity by invalid external references.

3.2.3 Core schemas for R1.5

Within the IFC Release 1.5 project scope the following core schemas are included. Note that IFC Release 1.0 included many of these resources.

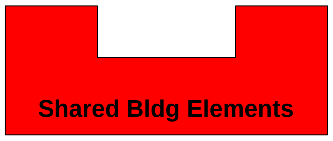
- IfcKernel
- IfcProductExtension
- IfcProcessExtension
- IfcModelingAidExtension
- IfcDocumentExtension

3.2.4 Core schemas for R2.5

Within the IFC Release 2.0 project scope the following core schemas are included.

- IfcKernel
- IfcProductExtension
- IfcProcessExtension
- IfcModelingAidExtension
- IfcDocumentExtension
- IfcProjectMgmtExtension
- IfcConstraintExtension

3.3 Interoperability Layer



The main goal in the design of Interoperability Layer is the provision of modules defining concepts or objects common to two or more domain/ application models. The commonly used, 'common concept' modules enable interoperability between different domain or application models. Introduction of this model layer is the best example of a general purpose model design guideline, that the model should incorporate a 'Plug-In' architecture -- allowing multiple domain or application models to be 'Plugged into' the common IFC Core. Such a 'Plug-In' architecture will also support outsourcing the development of domain/application models.

3.3.1 Interoperability schemas for R1.5

Within the IFC Release 1.5 project scope the following schemas are defined in the Interoperability layer:

- IfcSharedBldgElements (all fundamental building elements shared between domains)
- IfcSharedBldgServiceElements (all fundamental building service elements shared between domains)

3.3.2 Interoperability schemas for R2.0

Within the IFC Release 2.0 project scope the following schemas are defined in the Interoperability layer:

- IfcSharedBldgElements
- IfcSharedBldgServiceElements
- IfcSharedSpatialElements

3.3.3 Adapter Definitions

Although not yet used in the current IFC Release the concept of an 'adapter' is foreseen to access various domain models, including disperse models (i.e. those defined outside the International Alliance for Interoperability). The main requirements for Adapters are the facilitation of:

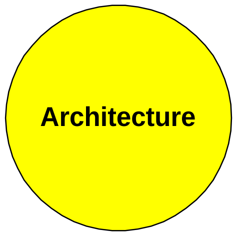
1. Direct Plug-In of IFC developed Domain Models, that is a direct reference and use of Core definitions by the appropriate Domain Models through the provision of interoperable class definitions at the Interoperability layer. This is currently the only applied technique.
2. Plug-In of externally developed, non harmonized, Domain Models via an Adapter that provides a mapping mechanism down to Core and Interoperability definitions. The definition of the Adapter Plug is in the responsibility of the Domain Model developer and is part of the Domain Model Layer.
3. Establish an inter-domain exchange mechanism above the Core to enable interoperability across domains. This includes a container mechanism to package information. Therefore an Adapter is used where the definition of the Adapter is the responsibility of all Domain Models sharing this Adapter Plug.

The Adapters are based on Core Extension definitions and enhance those Core Extension definitions. Those enhancements provide common concepts for all Domain Models that might further refine these concepts. As an example, the Building Element Socket provides the definition of a common wall, whereas the Architectural Domain Model will enhance this common wall with its private subtypes and type definitions within Release 3.0 time frame. An Adapter Socket that is used by several Domain Models therefore provides a medium level of interoperability through shared Adapter Socket definitions.

IFC Domain extensions that tightly couple with the Core Model such as those defined within the IFC Model (i.e., HVAC and Architecture) do not require an additional mapping of Domain Model definitions down to Core definitions, therefore they do not need specific Adapter.

Non-IFC harmonized models can be connected to the IFC Core Model through a mapping defined by a specific Adapter. This methods needs to be further elaborated within the Release 3.0 time frame. For specific high-level inter-domain exchange, that cannot be satisfied by common definitions in the Core, the Adapter may provide a specific inter-domain mapping. This Adapter type has to be developed within Release 3.0 time frame as well.

3.4 Domain/Applications Layer



Domain/Applications Models provide further model detail within the scope requirements for an AEC/FM domain process or a type of application. Each is a separate model which may use or reference any class defined in the Core and Independent Resource layers. Examples of Domain Models are Architecture, HVAC, FM, Structural Engineering etc. A main purpose of Domain Models is the provision of specialized type definitions that are tailored for the use within this domain.

Part of the Domain Model definition is the definition of the Adapter Plugs if needed. Fully harmonized IFC Domain Models will be directly plugged in the Core definitions. Domain Models which are non fully harmonized have to provide appropriate Adapter Plug definitions in order to be enabled to use the IFC model framework. The Adapter Sockets provide the guidelines to develop those Plugs. If inter-domain interoperability has to be achieved that extends the common shared Core definitions, those Domain Model developments have to be combined in order to provide an interoperable Plug.

3.4.1 Domain Models for R1.5

Within the IFC Release 1.5 project scope the following Domain Models are included:

- IfcArchitecture
- IfcFacilitiesMgmt

3.4.2 Domain Models for R2.0

Within the IFC Release 1.5 project scope the following Domain Models are included:

- IfcArchitectureDomain
- IfcFacilitiesMgmtDomain
- IfcHVACDomain
- IfcCostEstimatingDomain